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The use of natural gas and geothermal energy in school units. Greece: A case study

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ABSTRACT

The ever-increasing degradation of the environment along with high demands for energy consumption in buildings has prompted many countries to use other energy sources such as natural gas and geothermal energy instead of oil.

This study refers to the use of natural gas in school units in Greece. More specifically, it focuses on school units that are connected to the natural gas network and on the economic and environmental benefits arising from this.

In this context, the advantages and disadvantages in using natural gas are compared with those resulting from the use of geothermal energy. In areas which have a significant geothermal potential, the choice of geothermal heating and cooling of large school units is the best solution, but this however does not apply to all areas. Clearly, the development of geothermal energy in school units is still in pilot stage.

However, the use of natural gas in school units has been rising over the last decade and it has already contributed to some extent towards the reduction of carbon dioxide and towards saving natural resources. Thus, the survey shows clear advantages in using natural gas and in plans to extend its use to other school units.

Contents

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1. Introduction

In recent years a great effort is being carried out to reduce greenhouse gases that cause global warming. The use of natural gas to produce both electricity and heat has increased rapidly. The ultimate goal is to reduce the emissions of carbon dioxide produced by burning fossil fuels (oil).

The European Union under the Kyoto Protocol has undertaken the task to reduce greenhouse gas emissions on its territory by 8% during the period 2008–2012 [1]. By the year 2020 the reduction should be of 15% below the 1990 levels [2].

In recent years the EU has been implementing new policies in order to encourage an ever-increasing use of natural gas. The EU has also taken steps to deal with leaks in the gas distribution system. As will be shown below, the use of natural gas has lower CO_2 emissions than other fossil fuels [3].

Natural gas is a fuel with higher efficiency and lower emissions than other fossil fuels. For this reason it has been used in schools by the School Buildings Organization. The aim is to reduce CO_2 emissions [4] in the atmosphere and to protect the environment. The School Buildings Organization launched the use of geothermal energy in some school units as a pilot programme. The benefits of this type of energy will be analysed below.

Another aspect researched in this paper is the significant role in energy consumption of new techniques applied in the design of schools.

The environmentally friendly design of buildings is a complex task. The proper use of energy and the protection of the environment in buildings is challenging and depends on many factors related to the choice of construction materials, heating, ventilation, air conditioning (HVAC) and equipment, design, installation and use [5].

Thus, the new techniques refer to a bioclimatic construction of school units and the use of appropriate materials with a high degree of thermal insulation, among other factors.

2. Materials and methods

The present survey makes use of statistical data from the School Buildings Organization and the Gas Supply Companies (EPA) in connecting school units to the network of natural gas.

It also includes personal interviews with people of the School Buildings Organization, who are responsible for connecting and installing natural gas in school units.

The survey was carried out in school units in Attica and focuses on heating energy consumption using natural gas and geothermal energy. It concludes with an evaluation of the economic and environmental benefits that result from using natural gas and geothermal energy instead of fossil fuels, in this case oil.

3. Greece (case study)

In Greece there has been an increase in energy consumption of natural gas versus oil during the last decade (Fig. 1).

Table 1
Number of school units connected to the natural gas network in Greece [7–10].

Region	Total school units	Number of school units connected to the natural gas network.
East Macedonia and Thrace	842	2
Thessaly	1409	222
Central Macedonia	2464	390
Attica	3036	1201
Total	7751	1815

Table 2
School units (nursery schools, secondary schools and high schools) that are connected to the natural gas network during the period 09/2009 to 08/2010 in the Attica region [9,19].

Municipal districts	Total school units	School units that are connected to the natural gas network	
			(%)
Agioi Anargyroi	38	16	42.1
Agios Ioannis Rentis	18	12	66.7
Agias Varvaras	22	9	40.9
Agias Paraskevis	39	20	51.3
Agios Demetrious	53	22	41.5
Athens	463	322	69.5
Aigaleo	65	27	41.5
Alimos	28	6	21.4
Amarousio	57	55	96.5
Argyroupoli	36	11	30.6
Voulas	15	1	6.7
Vyronas	39	10	25.6
Galatsi	44	18	40.9
Glyfada	48	11	22.9
Dafni	19	9	47.4
Drapetsona	18	18	100.0
Eleusina	32	1	3.1
Elliniko	15	2	13.3
Ilioupoli	63	29	46.0
Irakleio	38	21	55.3
Ilion	79	21	26.6
Kaisariani	22	11	50.0
Kallithea	84	39	46.4
Kamatero	24	9	37.5
Keratsini	57	33	57.9
Kifisia	23	13	56.5
Korydallos	24	18	75.0
Lykovrysi	8	8	100.0
Melissia	13	4	30.8
Metamorfosi	21	8	38.1
Moschato	18	8	44.4
Nea Filadelfeia	30	7	23.3
Nea Ionia	56	37	66.1
Nea Smyrni	50	38	76.0
Nea Chalkidona	6	6	100.0
Nikaias	71	52	73.2
Paleo Faliro	37	29	78.4
Papagou	9	9	100.0
Piraeus	167	77	46,1
Peristeri	144	48	33.3
Petroupoli	39	10	25.6
Pefki	14	14	100.0
Tavros	17	7	41.2
Filothei	6	4	66.7
Chaidari	41	10	24.4
Chalandri	50	17	34.0
Cholargos	17	12	70.6
Psychiko	7	4	57.1
Total	1201	2284	52.6

The gas network has been extended to different areas of Greece. The main network currently travels through the regions of Thrace and Macedonia as far as Corinth. This implies that in the areas linked to the network of natural gas we have more connections of school units to this natural gas network (Fig. 2).

The main areas are located in Attica and Thessaloniki where there is a higher number of school units. In Attica, Thessaly and Thessaloniki, the company in charge of managing the supply of natural gas is the Gas Supply Company (EPA) and for the rest of Greece it is the Public Gas Corporation (DEPA).

According to the statistical data of these companies, the number of school units are connected to the natural gas network are the following:

Both the local municipalities and the School Buildings Organization have contributed to the connection of school units to the natural gas network as shown below:

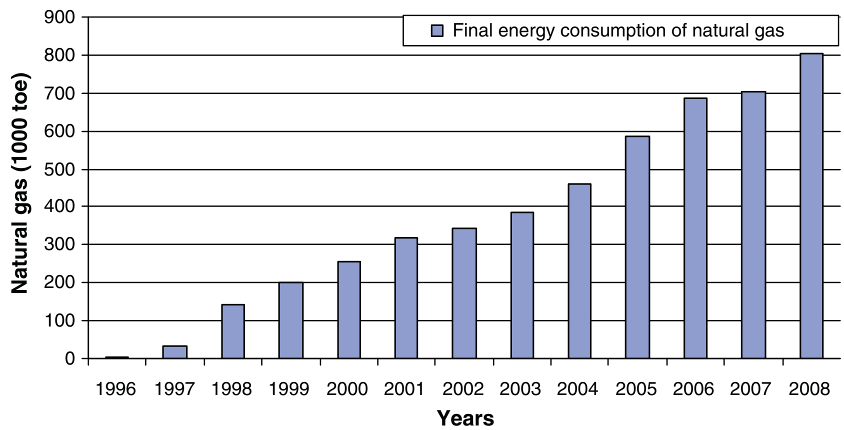

Fig. 1. Final energy consumption of natural gas in Greece [6].

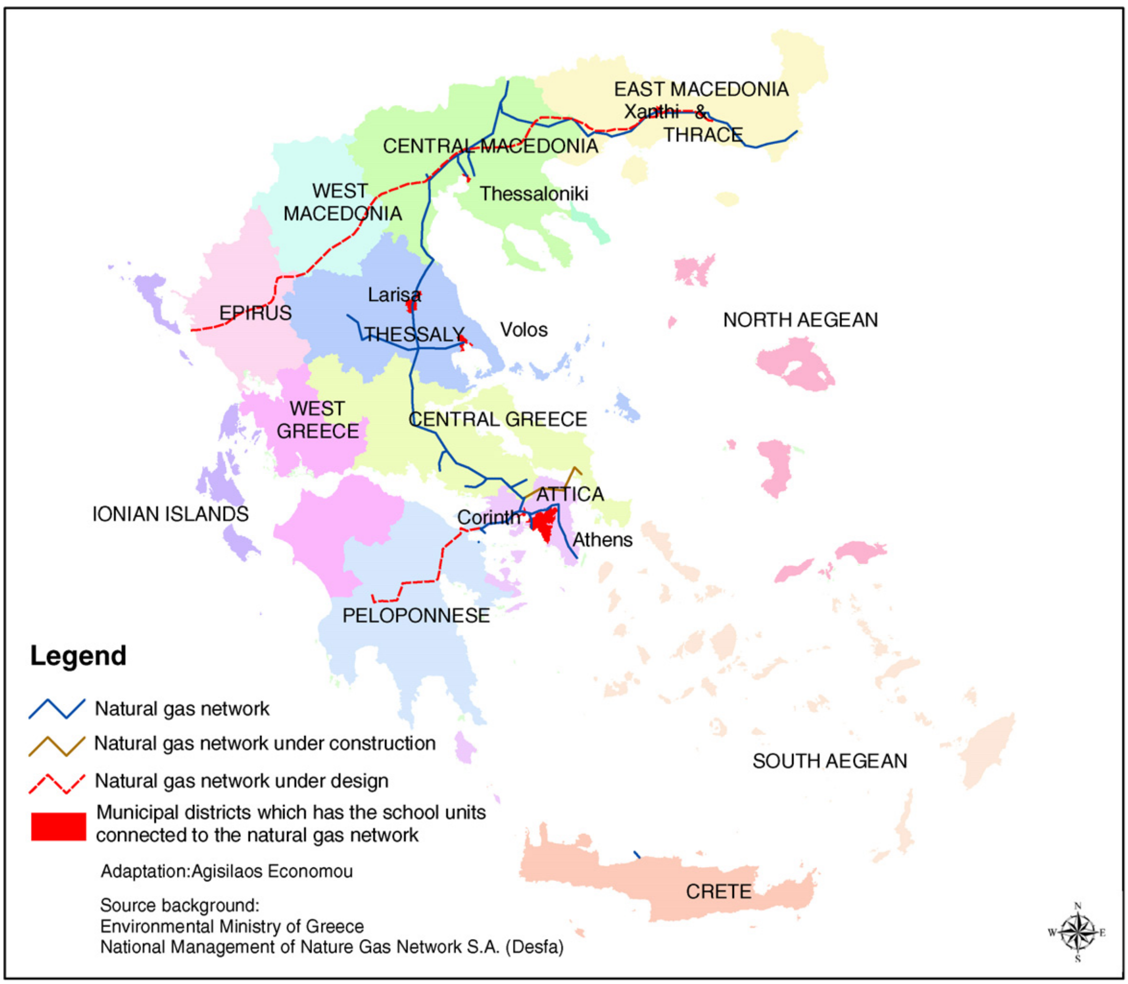

Fig. 2. Natural gas network in Greece and municipal districts where school units have been connected to the natural gas network.

Table 3
Use of natural gas for heating in school units in Athens during the time period 9/2009 to 8/2010 [9,11].

School units	Construction year	Total floor area (m^2)	Total volume of building	Total (kWh)	(kWh/m^3)
3th Nursery school in Paleo Faliro	1993	210.5	800	5444.558	6.81
48th Nursery school in Athens	1995	219.3	1025	15031.154	14.66
4th Nursery school in Kallithea	1999	103.68	443.75	3025.686	6.82
17th Nursery school in Piraeus	2003	301	1580	9296.725	5.88
13th Nursery school in Glyfada	2003	259.2	933.12	10329.791	11.07
60th Nursery school in Athens	2004	155.52	668.73	8710.848	13.03

Fig. 3. Municipal districts where school units have been connected to the natural gas network in the Attica region.

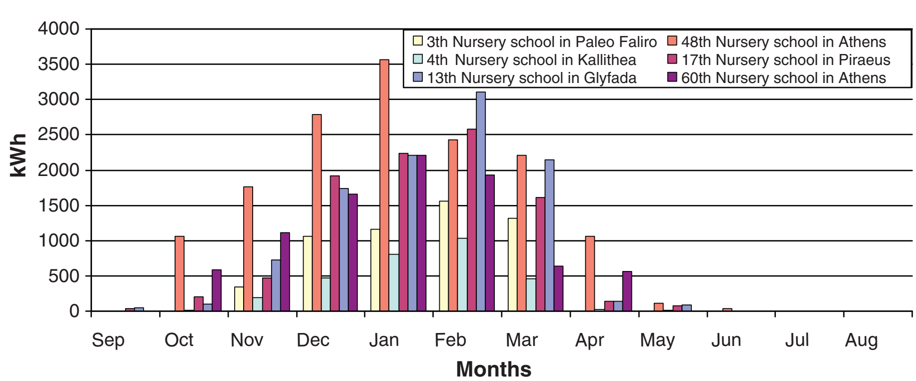

Fig. 4. Consumption of natural gas in school units in Athens during the period September 2009 to August 2010.

Table 4
Emission CO_2 (kgr) ratio the choice of fuel in school for disable children in Kallithea.

	Emission CO_2 (kgr)				
Choice of heating appliance	Consumption for heating	Lignite	Coal	Heating oil (Diesel)	Natural gas
Geothermal system	61307.25	24522.9 (100%)	20231.376 (82.5%)		
Natural gas	22637.219				49045.8 (50%)
Oil (Diesel)	23288.603			68664.1	

Production CO_2 during combustion: (Lignite 0.40 kg/kWh, Coal 0.33 kg/kWh, Oil heating (oil fuel) 0.26 kg/kWh, natural gas 0.20 kg/kWh) [15].
Period of heating 8 h/day × 125 days.

4. Results

A research carried out by the Greek School Buildings Organization resulted in the following:

- In 2004 the School Buildings Organization S.A. began studies to launch the project of connecting school units to the natural gas network. These studies are still underway.
- During the period 2004–2010, the efforts of the School Buildings Organization resulted in connecting 201 school units to the natural gas network (97 nursery schools, 43 elementary schools, 22 secondary schools, 38 high schools and 1 school for disabled children) [11]. At the same time, the efforts on the part of the various municipalities resulted in connecting many other school units to this network.
- The network has been and is being installed in compliance with the terms in the regulation for internal natural gas facilities, with an operating pressure of up to 1 bar [12].
- The objective of the School Buildings Organization is to expand the use of natural gas in school units as being more advantageous than the use of oil. Thus, all new school units are to be connected to the natural gas network wherever available.

The survey shows that by 2010 in Attica, 1201 school units had been connected to the natural gas network [9] (Fig. 3, Tables 1 and 2).

The survey, carried out in 6 schools in Attica, shows that the consumption of gas depends on the operating hours of the school units, the thermal insulation and weather conditions (Figs. 3 and 4, Table 3).

5. Geothermal energy

5.1. Use of geothermal energy in a school for disabled children in Kallithea

The School for disabled children in Kallithea was chosen as a case study for the use of geothermal energy. This is the first school unit in Greece to use geothermal energy. The area has a good geothermal potential and the school, due to the fact that it houses children with special needs, requires additional energy. Geothermal energy is used as a primary energy source to cover the needs for heating in the winter and cooling in the summer. At the same time, photovoltaic systems have been placed in the same school unit in order to cover a part of its needs in electricity.

For heating and cooling the school area (total floor area 2851.50 m^2, total volume 11019.52 m^3) the required heating load is 86 w/m^2 or 245.299 kWh and 72 w/m^2 or 205.308 kW for cooling [9]. The following are the energy requirements of the school unit when in operation:

For heating: 245.299 kW × 8 h/day × 125 days = 245,229 kWh

For cooling: 205.308 kW × 8 h/day × 90 days = 245,229 kWh

Table 5
Construction and operating cost for the geothermal unit in the school for disabled children in Kallithea.

Geothermal unit	Cost (Euro)
Construction	387401[9]
Heating	61307.25 × 0.08700
Cooling	41061.6 × 0.08700
Standing charge, customer charge	6.36
Total (heating, cooling, standing charge, customer charge)	(102368.85 + 6.36) × 0.08700 = 8906.64

With the use of geothermal energy [COP (coefficient of performance) = 4.5] the consumption is reduced to 1/4 of heating 61307.25 kWh and 1/5 for cooling 41061.6 kWh.

5.2. Other forms of energy

One part of the electricity needed to operate the geothermal unit will be provided by the photovoltaic systems installed and the rest by the existing network. Thus, the photovoltaic systems, with a total capacity of 13.8 kWp, will produced about 1330 kWh [14] which will be used to meet the needs of the school unit.

6. Discussion

The survey has shown that school units present different levels of fuel consumption for heating depending on the number of hours the burner is operating and the number of air conditioners.

Across the country the number of school units that are connected to the network of natural gas is relatively small. However, the expansion of the gas network to the rest of Greece will enable new school units to be connected to it.

6.1. Environmental impact

6.1.1. Use of natural gas in school units in Attica

Based on statistical data for the consumption of natural gas in all the schools in the Attica region, it has been found that the 1201 schools connected to the network during the school year 2009–2010, have consumed an equivalent of 49548.8 kWh in natural gas. Taking into account that the emitted carbon dioxide pollutants produced by burning natural gas (0.20 kg/kWh) and heating oil (0.28 kg/kWh) [15] respectively, it is clear that the use of natural gas has reduced emissions of CO_2 in Attica by (49548.8 × 0.20 kg/kWh–49548.8 kWh × 0.28 kg/kWh = 3.96 tons (as opposed to the use of oil).

6.1.2. Use of geothermal energy

The use of geothermal energy produces zero emissions in the atmosphere, provided that the electric energy that is required is produced by photovoltaic systems.

Thus, the environmental impact depends on the choice of fuel for the production of electricity (lignite, coal, oil, natural gas, water drop, and others) used to operate the geothermal system (Table 4).

Table 6
Comparison in cost savings in geothermal energy and natural gas for heating and cooling in the Kallithea School Unit for disabled children.

Types of energy	Heating	Cooling	Total	Cost
Geothermal	(1/4) × (needs of energy) = (1/4) × 245229 kWh = 61307.25	(1/5) × (needs of energy = (1/5) × 205308 kWh = 41061.6	102368.85	(102368.85 × 0.08700 = 8906.08
Natural gas			42757.40	42757.40 × 0.64206 = 27452.81
Benefits				27452.81 − 8906.08 = 18546.73

1 kWh = 0.08700 Euro [17].

6.2. Economic impact

6.2.1. Natural gas

In Attica, for the installation of natural gas in a school unit, the approval of the study and its implementation come at a cost. The cost for the approval of the study ranges between 76 and 700 Euros, depending on the size of the heated area. However, in Thessaloniki and Thessaly the approval of the study is free.

The cost for connection ranges from 36 to 500 Euros, depending on the size of the school. In addition to this, during the connection of the school unit to the network, problems arise related to the cost of construction of sidewalks over gas lines.

In financial terms the use of natural gas to heat the school area is more economical than oil because the price of oil is determined by the international oil price × 82% [16].

6.2.2. Geothermal energy

The construction cost of the geothermal system depends on the geothermal potential of the region and the total heating area of the school. For the school for disabled children in Kallithea, 3000 m of pipe are required to achieve a COP of 4.5 [13]. Therefore the construction and operating cost of a geothermal system in the school in Kallithea, where there is a low geothermal potential, (average annual temperature of the subsoil depth >3 m is about 8–12 °C while the outdoor temperature is 30–32 °C in summer and −15 to −20 °C in winter) [13] is shown in (Table 5).

7. Natural gas versus geothermal energy

Results for a comparison of geothermal energy and natural gas in the school unit for disabled children in Kallithea (Table 6):

The above table shows that the use of geothermal energy requires less energy and has a smaller cost than gas. This has resulted in lower operating costs. However, due to high construction costs for the school units in the Athens area, the depreciation period is 21 (cost/benefits = 387,401 Euro/18546.178 Euro = 20.88 years) years over a 25–30 year span [18].

With current prices, the use of natural gas is both financially and environmentally more efficient than oil. The connection of school units to the natural gas network has resulted in a reduction of the cost of consumption, due to the cost of oil, and in a significant reduction of pollutants that harm the environment and affect climate change.

Geothermal energy is the most beneficial in environmental terms. The choice of a geothermal unit in a school unit depends on the geothermal potential of the area, the cost of electricity as well as the energy needs of the school unit. The use of geothermal energy in school units is more advantageous for large schools and in areas with a high geothermal potential and low winter temperatures.

8. Conclusions

These results suggest that too small a number of schools have as yet been linked to the natural gas network. Generally speaking, the use of gas as opposed to that of oil helps reduce energy consumption, and results in a financial profit of 18%. On the other hand, it reduces gas pollutants which have a negative impact on climate change. This makes the use of natural gas a better economical and environmental solution for areas that are linked to a natural gas network and have a low geothermal potential. Therefore, linking schools to the gas network and expanding the gas network to other parts of Greece is profitable.

However, research has shown that the benefits of geothermal energy are greater than the benefits of natural gas. Therefore, in areas with a high geothermal potential and low winter temperatures, the implementation of geothermal systems over natural gas is a better solution.

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